Multivariate Time Series Forecasting with Deep Learning

Kao Panboonyuen, Ph.D.

Contact: panboonyuen.kao@gmail.com

Code: https://github.com/kaopanboonyuen/GISTDA_TRAINING_2023

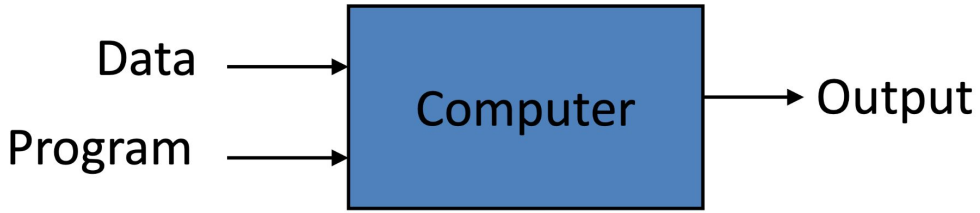
Outlines

1. Introduction to Machine Learning/Deep Learning
2. Basic Pandas
3. Regression
4. SARIMA**X** and Exercise with GISTDA Ocean Current Data
5. illustrated Guide to LSTM and GRU

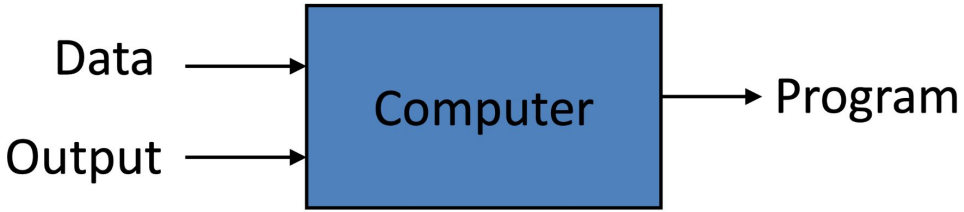
Code: https://github.com/kaopanboonyuen/GISTDA_TRAINING_2023

Introduction to Machine Learning/Deep Learning

Traditional Programming



Machine Learning



Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

Types of Learning

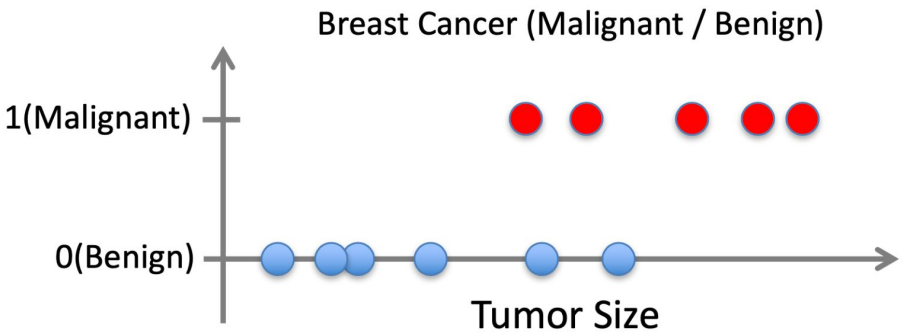
- Supervised (inductive) learning
  - Given: training data + desired outputs (labels)
- Unsupervised learning
  - Given: training data (without desired outputs)
- Semi-supervised learning
  - Given: training data + a few desired outputs
- Reinforcement learning
  - Rewards from sequence of actions

Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

Supervised Learning: Classification

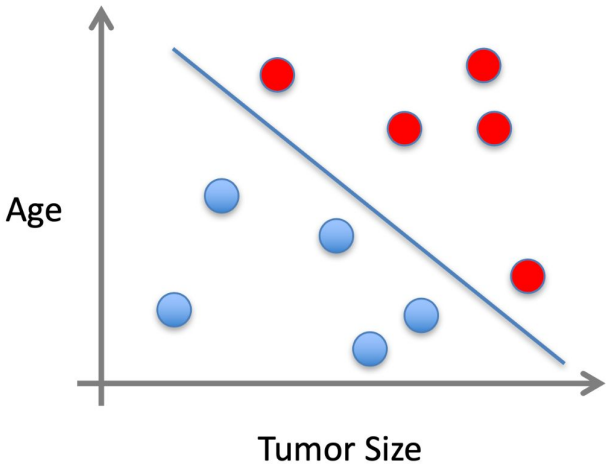
- Given (x_1, y_1), (x_2, y_2), …, (x_n, y_n)
- Learn a function $f(x)$ to predict y given x
  - y is categorical == classification



Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

- x can be multi-dimensional
  - Each dimension corresponds to an attribute



- Clump Thickness
- Uniformity of Cell Size
- Uniformity of Cell Shape

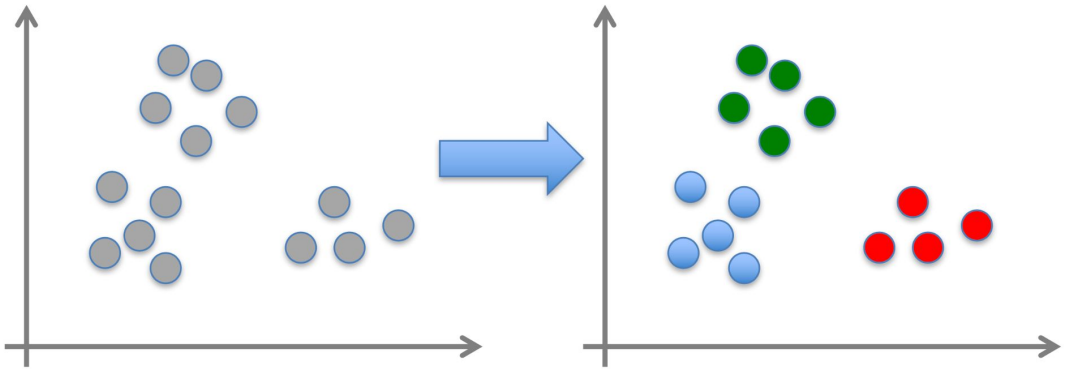
...

Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

Unsupervised Learning

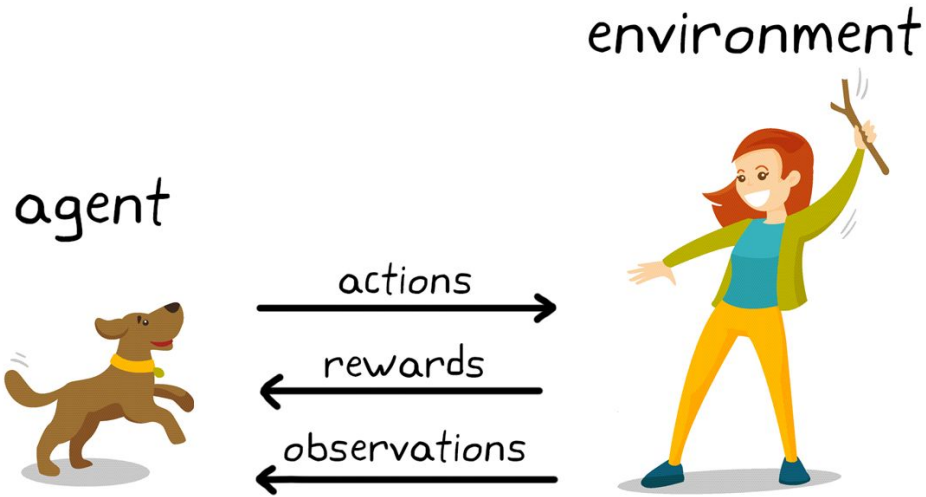
- Given x_1, x_2, ..., x_n (without labels)
- Output hidden structure behind the x's
  - E.g., clustering



Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

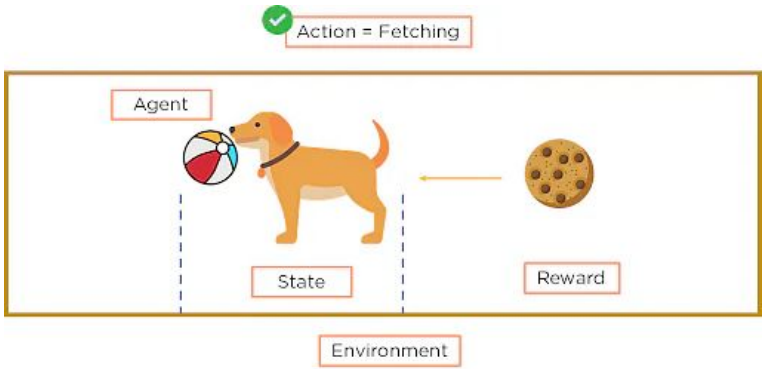
Reinforcement Learning

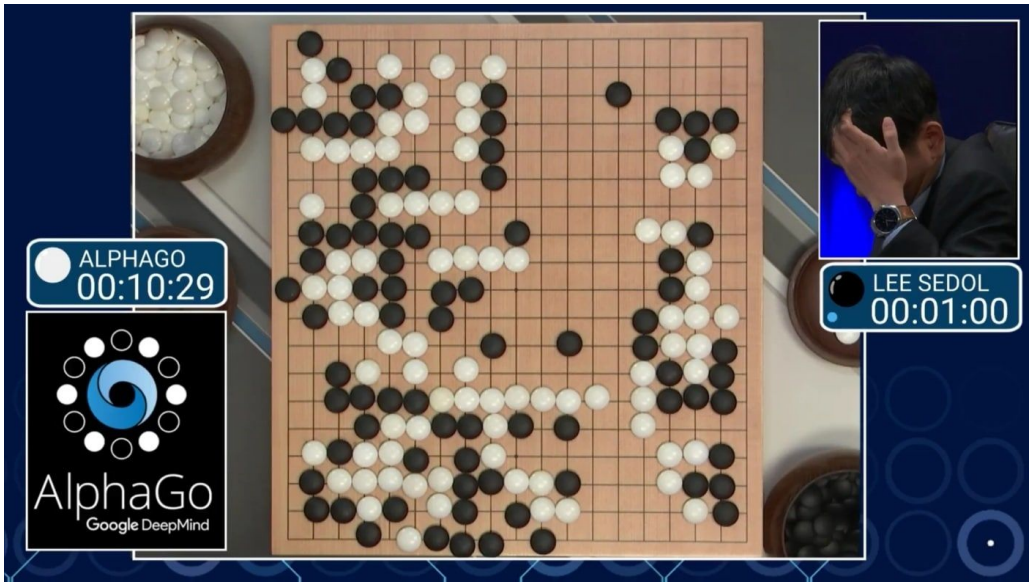


Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

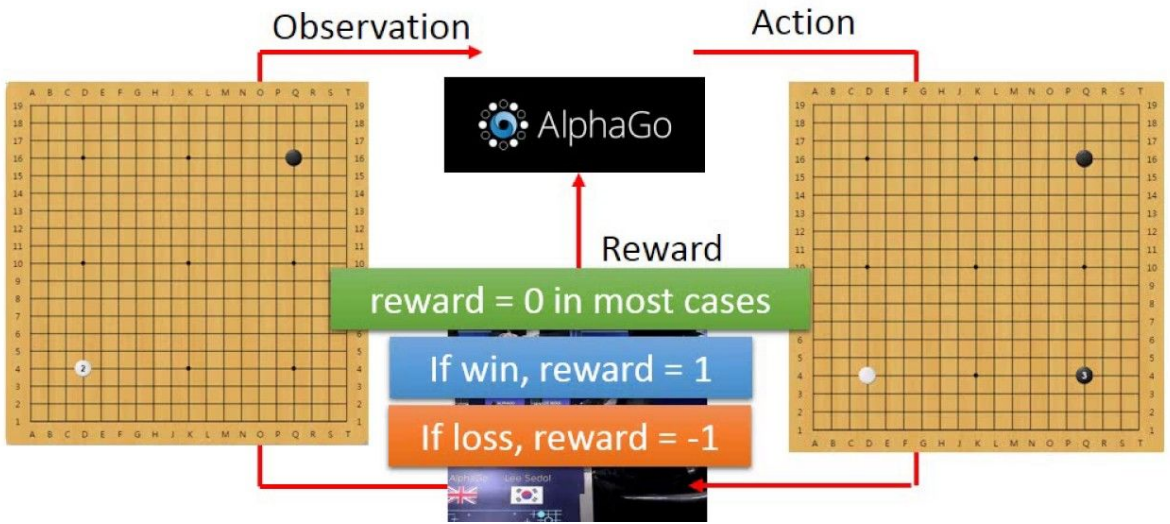
Reinforcement Learning





Introduction to Machine Learning/Deep Learning (Cont.)

Reinforcement Learning



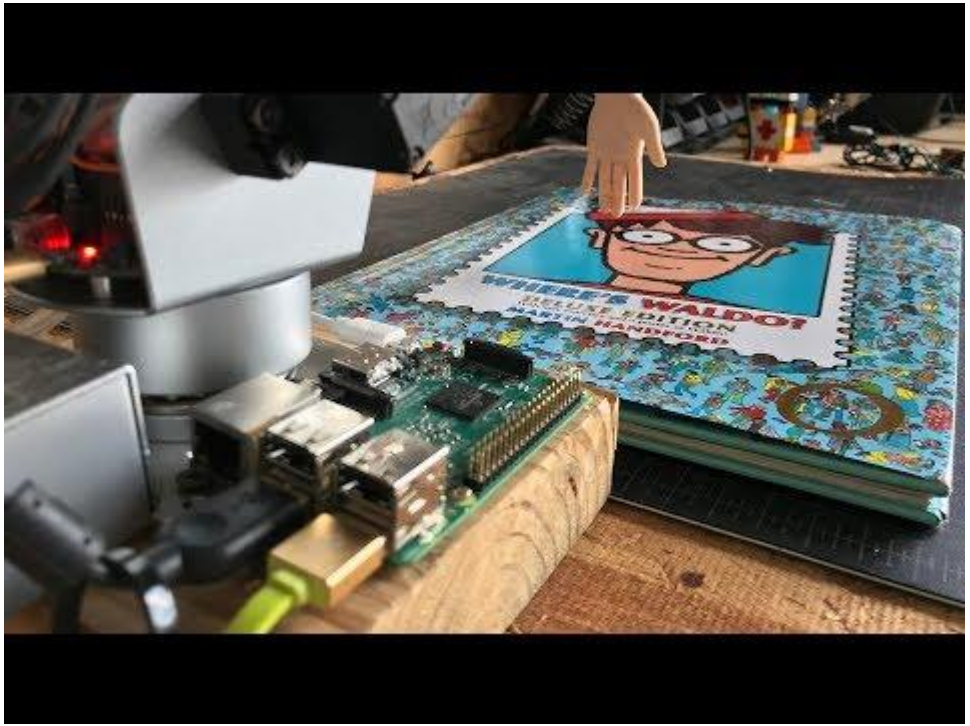
Credit: CIS 419/519 Introduction to Machine Learning Instructor: Eric Eaton

Introduction to Machine Learning/Deep Learning (Cont.)

Reinforcement Learning

Introduction to Machine Learning/Deep Learning (Cont.)

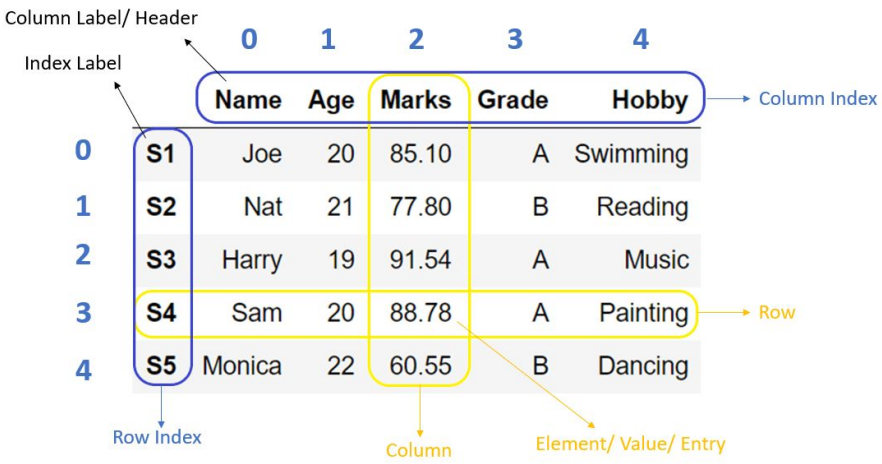
Convolution Neural Network

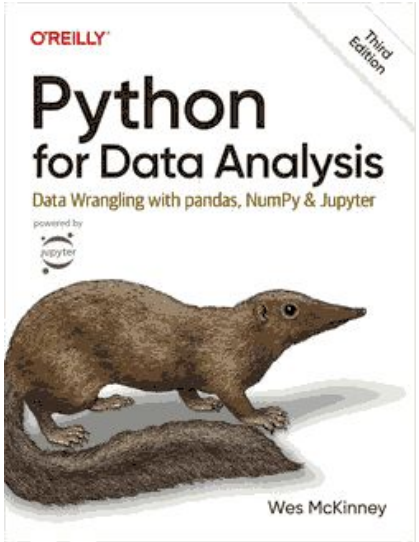


Basic Pandas

Pandas is a fast, powerful, flexible and easy to use open source data analysis and manipulation tool,

built on top of the Python programming language.



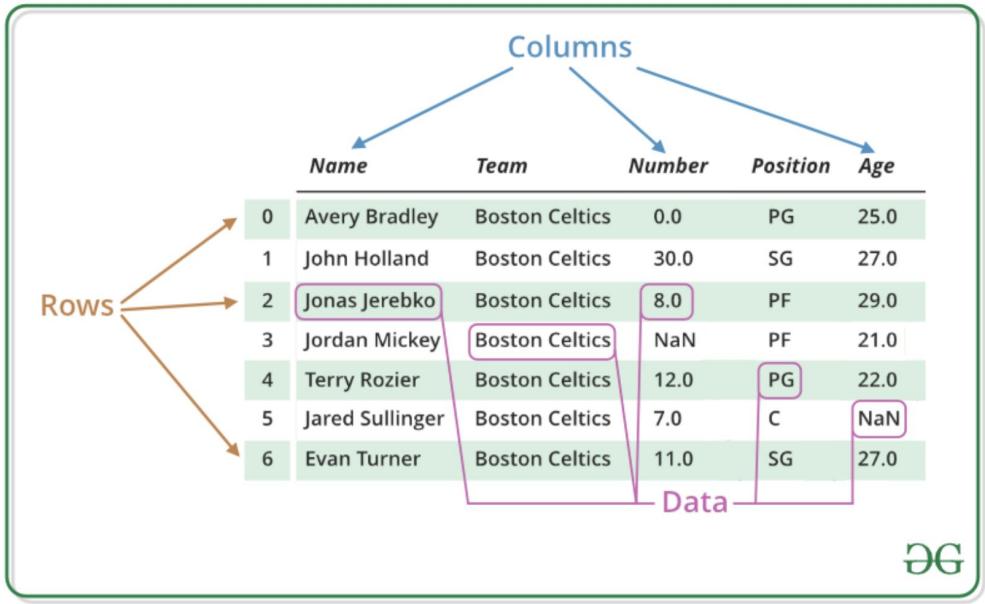


Basic Pandas (Cont.)

What Can You Do With **DataFrames Using Pandas**?

Pandas makes it simple to do many of the time consuming, repetitive tasks associated with working with data, including:

- **Data cleansing**
- **Data fill**
- **Data normalization**
- **Merges and joins**
- **Data visualization**
- **Statistical analysis**
- **Data inspection**
- **Loading and saving data**
- **And much more**

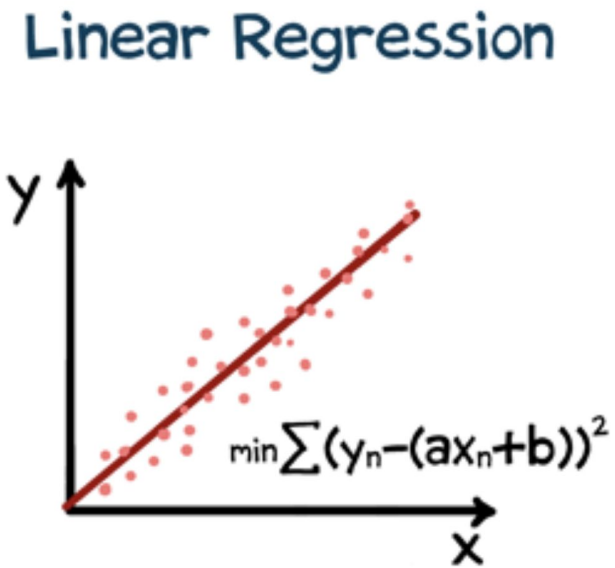


Part 1: Pandas Code

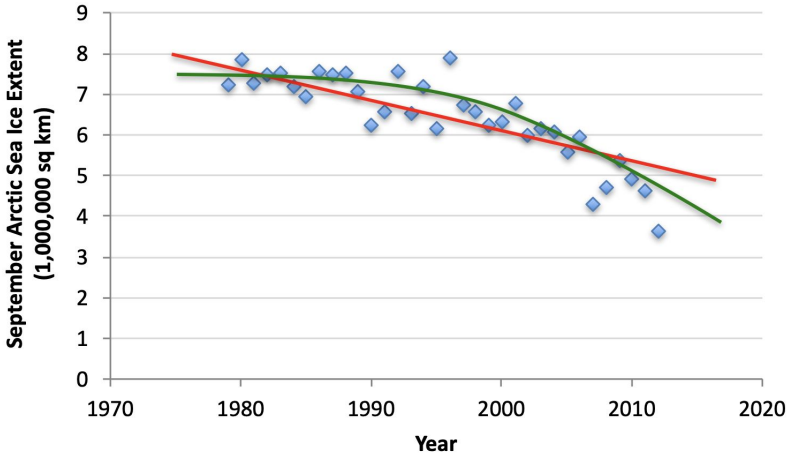
https://colab.research.google.com/github/kaopanboonyuen/GISTDA_TRAINING_2023/blob/main/code/C1-BasicPandas.ipynb

Regression

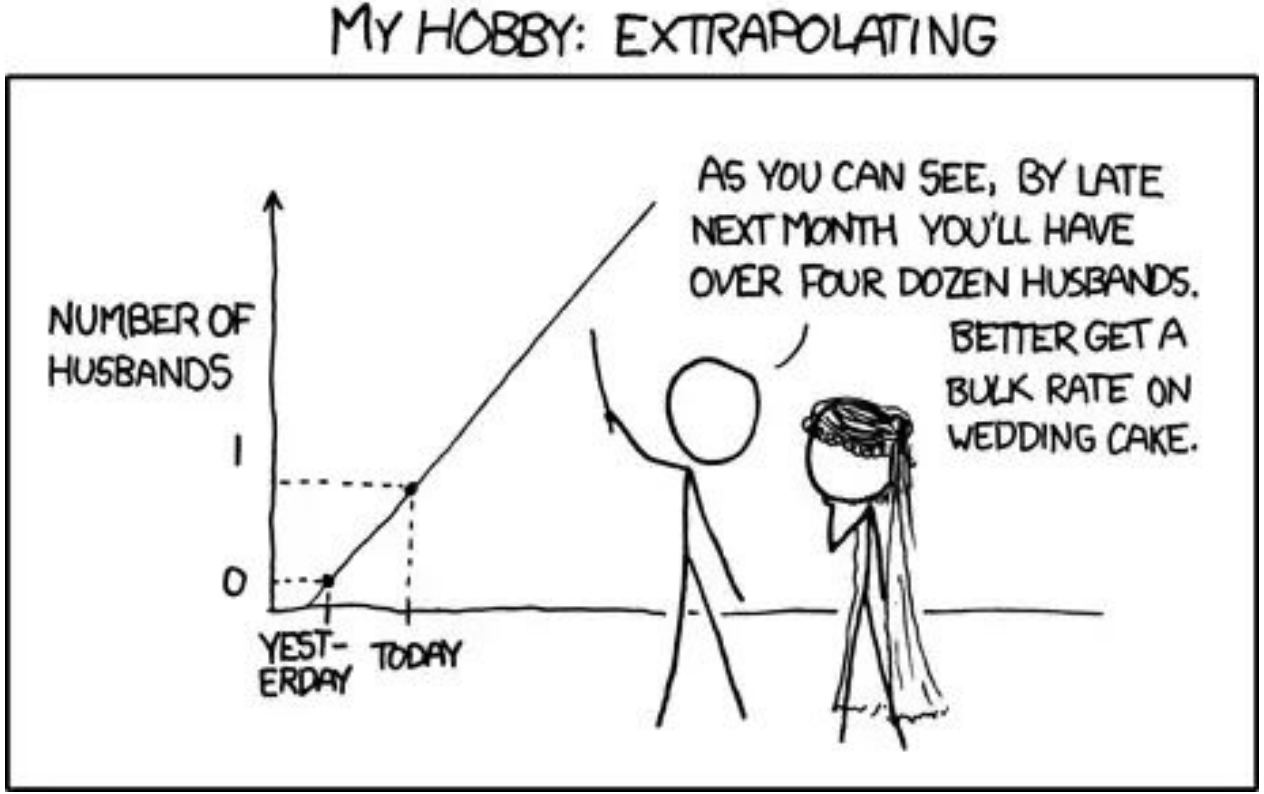
Supervised Learning: Regression



- Given (x_1, y_1), (x_2, y_2), …, (x_n, y_n)
- Learn a function $f(x)$ to predict y given x
  - y is real-valued == regression



Regression (Cont.)



Regression (Cont.)

Types of Linear Regression

Linear regression can be further divided into two types of the algorithm:

Simple Linear Regression:

If a single independent variable is used to predict the value of a numerical dependent variable, then such a Linear Regression algorithm is called Simple Linear Regression.

Multiple Linear regression:

If more than one independent variable is used to predict the value of a numerical dependent variable, then such a Linear Regression algorithm is called Multiple Linear Regression.

Part 2: Regression Code

https://colab.research.google.com/github/kaopanboonyuen/GISTDA_TRAINING_2023/blob/main/code/C2-Regression.ipynb

SARIMAX

SARIMA stands for **Seasonal Autoregressive Integrated Moving Average** (quite a mouthful).

SARIMAX (Seasonal Autoregressive Integrated Moving Average **with eXogenous factors**)

It's very much like ARIMA but more powerful.

We can use statsmodels' implementation of SARIMA.

$$SARIMA \underbrace{(p,d,q)}_{non-seasonal} \underbrace{(P,D,Q)_m}_{seasonal}$$

SARIMAX (cont.)

Orders of the SARIMA model

A SARIMA model can be tuned with two kinds of orders:

(p,d,q) order, which refers to the order of the time series. This order is also used in the ARIMA model (which does not consider seasonality);

(P,D,Q,M) seasonal order, which refers to the order of the seasonal component of the time series.

SARIMAX (cont.)

(P,D,Q,M) Order

The (P,D,Q,M) Order refers to the seasonal component of the model for the Autoregressive parameters, differences, Moving Average parameters, and periodicity:

D indicates the integration order of the seasonal process (the number of transformation needed to make stationary the time series)

P indicates the Autoregressive order for the seasonal component

Q indicated the Moving Average order for the seasonal component

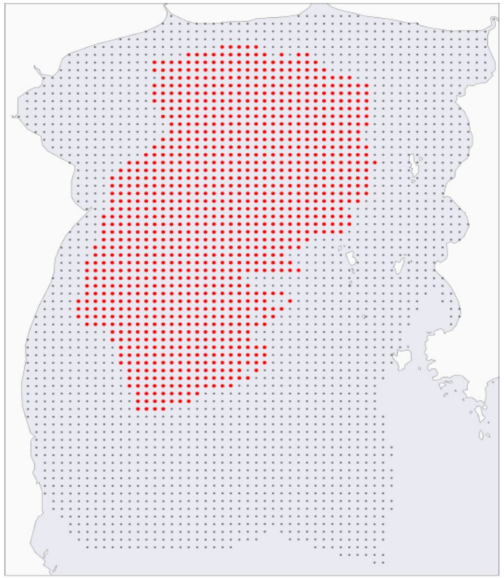
M indicates the periodicity, i.e. the number of periods in season, such as 12 for monthly data.

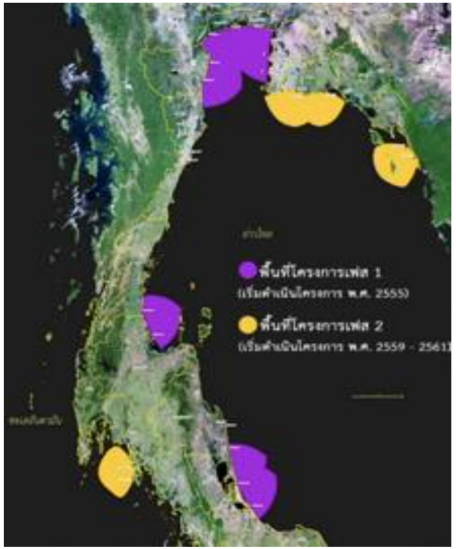
Part 3: SARIMAX Code and GISTDA Ocean Data Exercise

https://colab.research.google.com/github/kaopanboonyuen/GISTDA_TRAINING_2023/blob/main/code/C3-SARIMAX.ipynb

Exercise with GISTDA Ocean Current Data Set

https://colab.research.google.com/github/kaopanboonyuen/GISTDA_TRAINING_2023/blob/main/code/C3-SARIMAX.ipynb

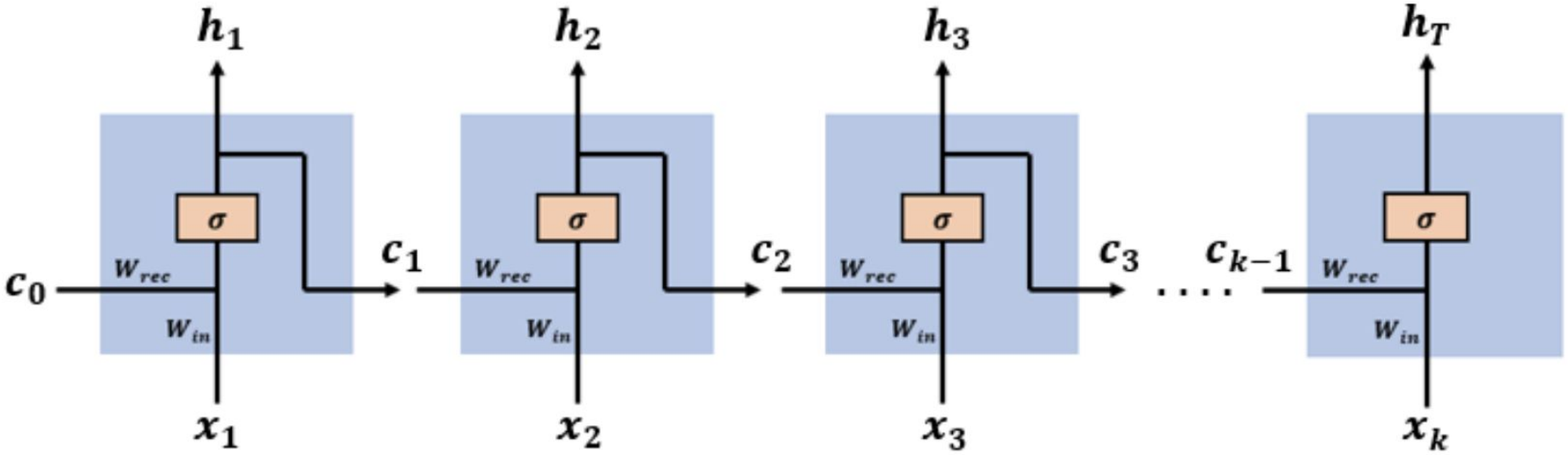




HF radar stations' area for both two phases (from https://www.gistda.or.th).

illustrated Guide to LSTM and GRU

RNN (Recurrent Neural Networks)



Credit: https://www.analyticsvidhya.com/blog/2022/01/tutorial-on-rnn-lstm-gru-with-implementation/

illustrated Guide to LSTM and GRU (Cont.)

RNN takes input as time series (sequence of words), we can say RNN acts like a memory that remembers the sequence.

the **LSTM (Long -short-term memory)** and **GRU (Gated Recurrent Unit)** have gates as an internal mechanism, which control what information to keep and what information to throw out.

By doing this LSTM, GRU networks solve the exploding and vanishing gradient problem.

Credit: https://www.analyticsvidhya.com/blog/2022/01/tutorial-on-rnn-lstm-gru-with-implementation/

illustrated Guide to LSTM and GRU (Cont.)

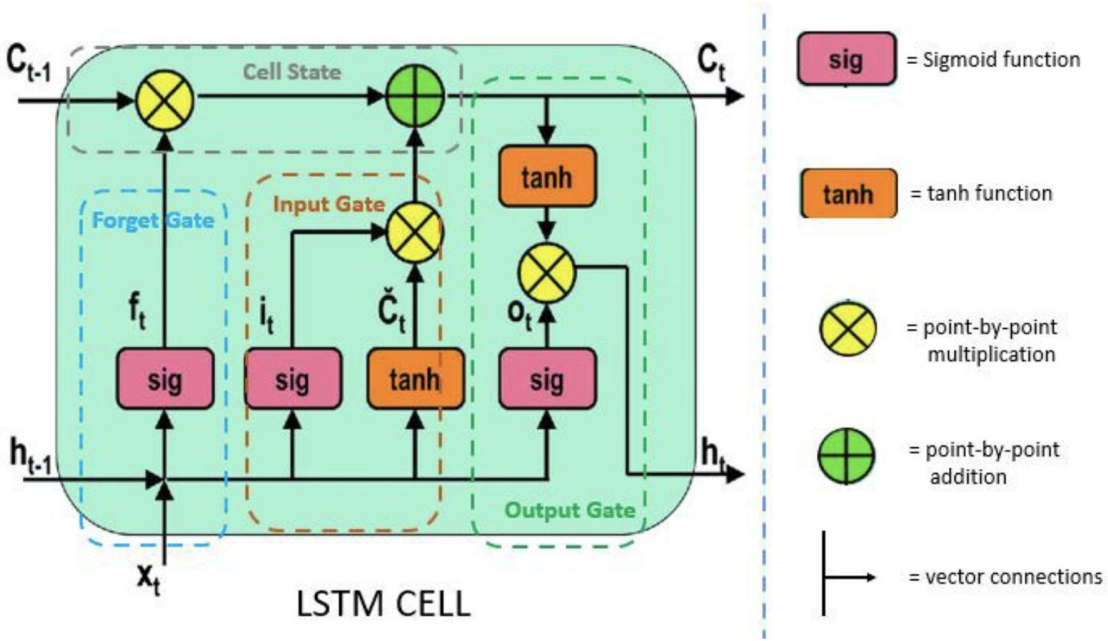
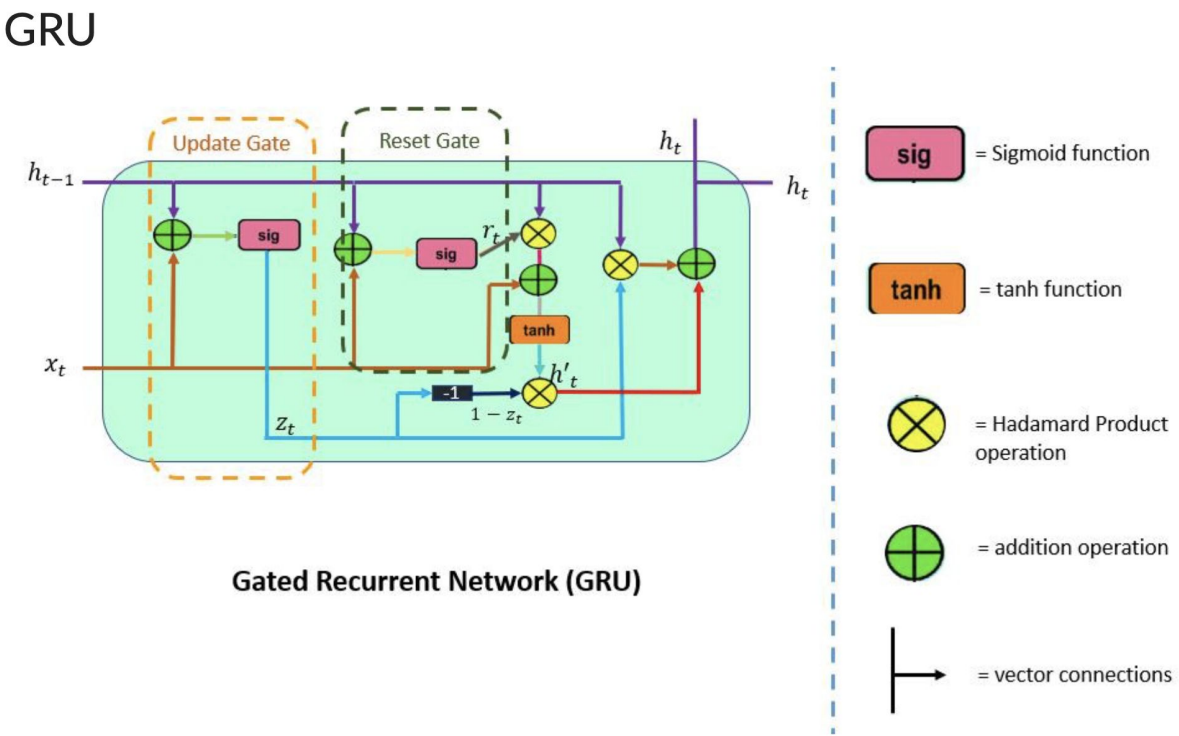


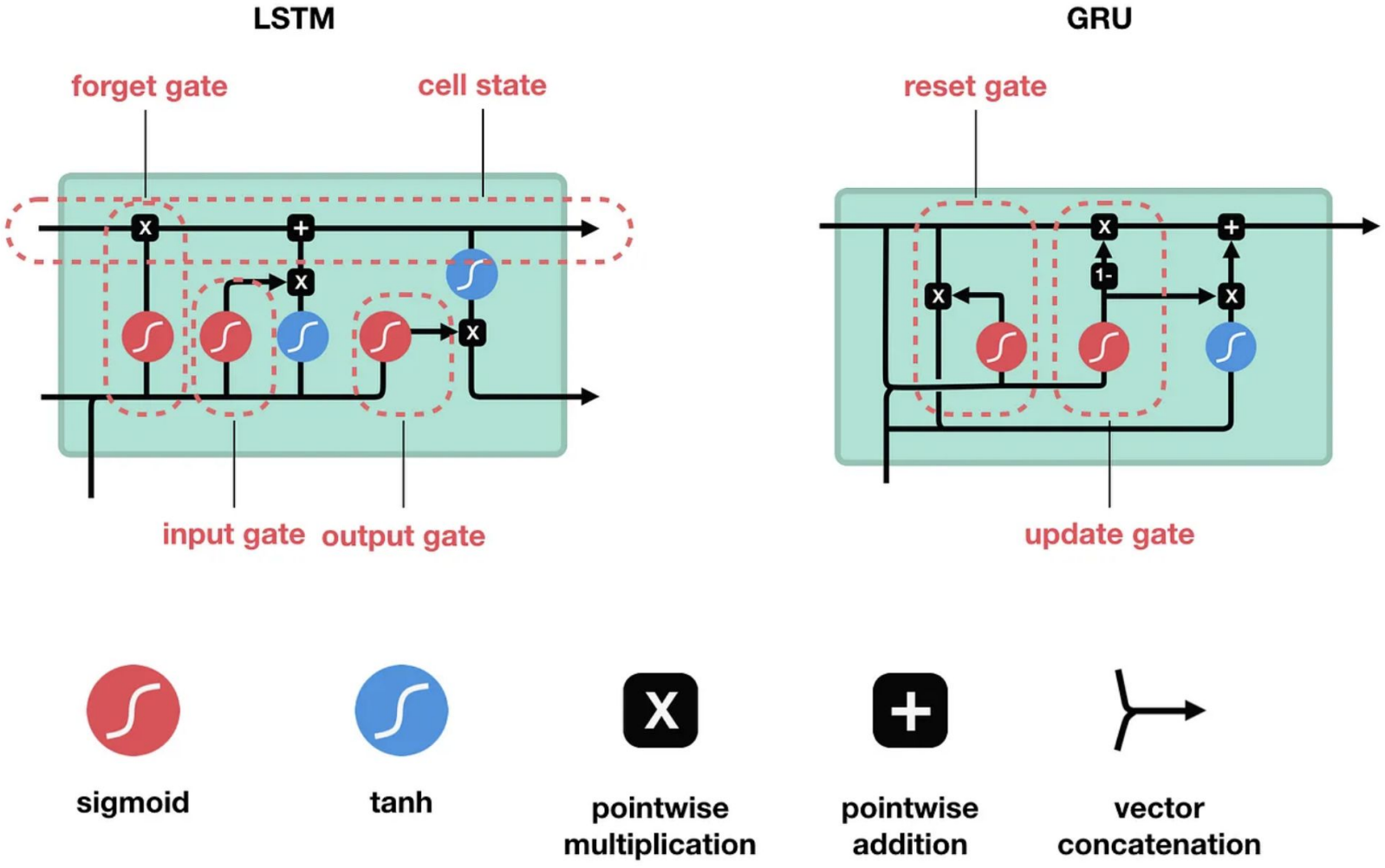
Image Source

Credit: https://www.analyticsvidhya.com/blog/2022/01/tutorial-on-rnn-lstm-gru-with-implementation/

illustrated Guide to LSTM and GRU (Cont.)



Credit: https://www.analyticsvidhya.com/blog/2022/01/tutorial-on-rnn-lstm-gru-with-implementation/


LSTM
forget gate
cell state
input gate
output gate
GRU
reset gate
update gate
1-
sigmoid
tanh
pointwise multiplication
pointwise addition
vector concatenation

Part 4: Deep Learning (LSTM and GRU) Code

https://colab.research.google.com/github/kaopanboonyuen/GISTDA_TRAINING_2023/blob/main/code/C4-LSTM-GRU.ipynb

Thank you

- All python codes/notebooks and lecture slide will be store through this github link https://github.com/kaopanboonyuen/GISTDA_TRAINING_2023